B-09-6C2
#1

Project:
Benchmark Energy Use

Principal Investigator:
David E. White

Date:
May 20, 2005

Sponsor:
SAIC
John L. Nicol, Technical Contact
Suite 201
5609 Medical Center Drive
Madison, WI 53719

Budget:
$4900

Scope:
Provide the total mill energy use for five cases (Appendix I, Table I-A), broken down into major unit operations (Table I-B). Use IPST Economic Model (Appendix II) and appropriate additional information to provide the total mill energy for the five cases. Use base case data in the IPST Economic Model as primary data for the liner and fine paper cases. Use literature data and other sources to estimate the tissue and coated paper cases, since the IPST Economic model does not currently include those grades.

The paper machine data had already been provided (Table I-A) and were used as-is, pending review versus IPST data. Results were to be reported in a brief report with tables formatted as Table I-B; e.g., Item 2 in Table I-A would be summarized as shown in Table I-B. The Principle Investigator on this project is David E. White (Appendix III).

Results:
Results are shown in summary form in Table A, with details in Tables B-F. These results were e-mailed to John Nicol on March 23, 2005. The approach for each area of the mill is itemized below. Where the recommended value was different from the IPST model value, the recommended value was adjusted from the IPST model value to be consistent with the total steam usage or power result provided by Jaakko Pöyry (Appendix I).

- Papermachine Energy Usage
  - Values from Jaakko Pöyry as provided by Ben Thorp (1) (Appendix I, Table I-A).

- Total Energy Use

- Values from Jaakko Pöyry as provided by Ben Thorp (1) (Appendix I, Table I-A), unless modified as indicated in Tables B-F.
- Note that three of the total steam consumption values (fine paper; coated 1s, 2s, 3s; recycled tissue) and one of the total power consumption values (recycled tissue) were changed to make the overall results consistent with the sum of the mill unit operation values; no adjustment was greater than 20%.

- Woodhandling
  - For power, used 15 kwh/fst for coated 4s, 5s - based on (a) IPST model: 48 kwh/fst for newsprint woodhandling and (b) groundwood: 33% of the furnish.

- Pulping, Mechanical Pulp
  - For steam, used 1.3 MM BTU/fst for coated 4s, 5s, based on (a) estimate of 4.7 MM BTU/fst for TMP (2) and (b) groundwood being 33% of furnish.
  - For power, used 575 kwh/fst for coated 4s, 5s, based on (a) IPST model: 1900 kwh/fst for TMP and (b) groundwood: 33% of the furnish.

- Bleaching
  - For steam, used 0.1 MM BTU/fst for coated 4s, 5s (33% of furnish; single stage) and 0.5 MM BTU/fst for recycled tissue; IPST model has 1.3 MM BTU/fst for 4-stage virgin fiber bleach plant.
  - For power, used 10 kwh/fst for coated 4s, 5s (33% of furnish; single stage) and 50 kwh/fst for recycled tissue; IPST model has 121 kwh/fst for 4-stage virgin fiber bleach plant.

- Recycle Plant
  - For steam, used 0.8 MM BTU/fst for recycled liner; IPST model has 0.1-0.6 MM BTU/fst for recycled liner and news base demand, respectively. Used 1.8 MM BTU/fst for recycled tissue; IPST model has 2.3 MM BTU/fst for news base demand plus deinking.
  - For power, used 110 kwh/fst for recycled liner; IPST model has 173-186 kwh/fst for recycled liner and news, respectively. Used 300 kwh/fst for recycled tissue; IPST model has 303 kwh/fst for news base demand plus deinking.

- Market Pulp Repulper
  - For steam, used 0.6 MM BTU/fst for non-integrated fine paper and for coated 1s, 2s, and 3s; IPST model has 0.1-0.6 MM BTU/fst for recycled liner and news base demand, respectively. Used 0.2 MM BTU/fst for coated 4s, 5s, since market pulp is 33% of the furnish.
  - For power, used 90 kwh/fst for non-integrated fine paper and 100 kwh/fst for coated 1s, 2s, and 3s; IPST model has 96 kwh/fst for news. Used 30 kwh/fst for coated 4s, 5s, since market pulp is 33% of the furnish.

- Utilities

- As approximation for steam, used 5% of total mill steam use (from IPST Economic model (Appendix II)
- As approximation for power, used 30 kwh/fst based on 40 kwh/fst for utilities and effluent from IPST Economic model.

References

1. Thorp, B. A., E-mail to D. E. White, "Benchmark Data From Jaakko Pöyry", December 7, 2004.
2. Private Correspondence, Draft Document, " Rough Summary of Process Energy Consumption in the Pulp and Paper Industry", February, 2005.

TABLE A
SUMMARY RESULTS, ALL GRADES EVALUATED *

	Recycled Linerboard	Fine Paper (not integrated)	Coated 1s,2s,&3s	Coated 4s&5s	Recycled Tissue
Woodhandling				0 / 15 / 0	
Pulping: Mechanical Pulp				1.3 / 575 / 0	
Pulping: Market Pulp Repulper		0.6 / 90 / 0	0.6 / 100 / 0	0.2 / 30 / 0	
Recycle Plant	0.8 / 110 / 0				1.8 / 300 / 0
Bleaching				0.1 / 10 / 0	0.5 / 50 / 0
Papermachine	4 / 310 / 0	3.9 / 410 / 0	4.5 / 590 / 0	4.7 / 600 / 0	4.2 / 581 / 1.8
Utilities	0.3 / 30 / 0	0.3 / 30 / 0	0.3 / 30 / 0	0.4 / 30 / 0	0.6 / 30 / 0
TOTAL	5.1 / 450 / 0	4.8 / 530 / 0	5.4 / 720 / 0	6.7 / 1260 / 0	7.1 / 961 / 1.8

* All table entries are:
Steam (MMBTU/fst)/ Power (kwh/fst) / Gas (MMBTU/fst)
Where fst is finished short ton

TABLE B
RECYCLED LINERBOARD

	Steam	Power	Gas		Comments, Steam	Comments, Power
	(MM BTU/fst)	(kwh/fst)	(MM BTU/fst)			
Recycle Plant	0.8	110			IPST Model: 0.1 - 0.6 for recycled liner and news, base demand, respectively; use 0.8	IPST Model: 173-186 for recycled news and liner, respectively; use 110
*Utilities	0.3	30			IPST Model: use 5% of total steam (0.25); use 0.3	IPST Model: 40 for news, utilities plus effluent; use 30
Paper Machine	4	310			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)
Total	5.1	450			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)

Recycled Liner
Fiber recycled on-site
Thermal energy generated on-site
Power purchased
Utilities includes waste water
Paper Machine includes stock prep.
fst = finished short ton (5% moisture)

TABLE C
FINE PAPER
(Not Integrated)

	Steam (MM BTU/fst)	Power (kwh/fst)	Gas (MM BTU/fst)		Comments, Steam	Comments, Power
Market pulp repulper	0.6	90			IPST Model: 0.1 - 0.6 for recycled liner and news, base demand, respectively; use 0.6	IPST Model: 96 for market pulp repulper (news); use 90
Utilities	0.3	30			IPST Model: use 5% of total steam (0.24); use 0.3	IPST Model: 40 for news, utilities plus effluent; use 30
Paper Machine	3.9	410			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)
Total	4.8	530			Changed total from 5.9 (Value given, Jaakko Pöyry (1)) to 4.8	Value given, Jaakko Pöyry (1)

Fine Paper
Fiber purchased as market pulp
Thermal energy generated on-site (?)
Power purchased
Utilities includes waste
water
fst = finished short ton (5% moisture)

TABLE D
COATED 1s, 2s, and 3s

	Steam	Power	Gas		Comments, Steam	Comments, Power
	(MM BTU/fst)	(kwh/fst)	(MM BTU/fst)			
Market pulp repulper	0.6	100			IPST Model: 0.1 - 0.6 for recycled liner and news, base demand, respectively; use 0.6	IPST Model: 96 for market pulp repulper (news); use100
Utilities	0.3	30			IPST Model: use 5% of total steam (0.3); use 0.3	IPST Model: 40 for news, utilities plus effluent; use 30
Paper Machine	4.5	590			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)
Total	5.4	720			Changed total from 6.7 (Value given, Jaakko Pöyry (1)) to 5.4	Value given, Jaakko Pöyry (1)

Coated 1,2,3
Chemical fiber is purchased as market pulp
Thermal energy generated on-site (?)
Power purchased
Utilities includes waste water
fst = finished short ton (5% moisture)

TABLE E
COATED 4s and 5s

	Steam	Power	Gas		Comments, Steam	Comments, Power
	(MM BTU/fst)	(kwh/fst)	(MM BTU/fst)			
Woodhandling	-	15	-			IPST Model: newsprint woodhandling: 48 kwh/fst; use 15 for 33% of furnish
Pulping: Mechanical Pulp	1.3	575			TMP: 4.7 MM BTU/fst; 1.5 for 33% of furnish: use 1.3	IPST Model, 1900 kwh/fst; 633 for 33% of furnish: use 575
Pulping: Market Pulp Repulper	0.2	30			IPST Model: 0.1 - 0.6 MM BTU/fstfor recycled liner and news, base demand, respectively; 0.03-0.2 for 33% of furnish: use 0.2	IPST Model: 96 kwh/fst for market pulp repulper (news); 32 for 33% of furnish: use 30
Bleaching	0.1	10			IPST Model: 1.3 MM BTU/fst for 4-Stage bleach plant; use 0.1 for 33% of furnish and 1 stage	IPST Model: 121 kwh/fst for 4-stage bleach plant; use 10 for 33% of furnish and 1 stage
Utilities	0.4	30			IPST model: use 5% of total steam (0.3); use 0.4	IPST Model: 40 for news, utilities plus effluent; use 30
Paper Machine	4.7	600			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)
Total	6.7	1260			Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)

Coated 4,5

Chemical fiber is purchased as market pulp (33% of furnish)
Groundwood is produced on-site; assume TMP (33% of furnish)
Thermal energy generated on-site
Power purchased
Utilities includes waste water
fst = finished short ton (5% moisture)

TABLE F
RECYCLED TISSUE

	Steam	Power	Gas	Comments, Steam	Comments, Power
	(MM BTU/fst)	(kwh/fst)	(MM BTU/fst)		
Recycle Plant	1.8	300	-	IPST Model: 2.3 for news base demand plus deinking; use 1.8	IPST Model: 303 for news; use 300
Bleaching	0.5	50		IPST Model: 1.3 MM BTU/fst for 4-Stage virgin fiber bleach plant; use 0.5	IPST Model: 121 kwh/fst for 4-stage virgin fiber bleach plant; use 50
Utilities	0.6	30	-	IPST Model: use 5% of total steam (0.55); use 0.6	IPST Model: 40 for news, utilities plus effluent; use 30
Paper Machine	4.2	581	1.8	Value given, Jaakko Pöyry (1)	Value given, Jaakko Pöyry (1)
Total	7.1	961	1.8	Changed total from 11 (Value given, Jaakko Pöyry (1)) to 12.1	Changed total from 626 (Value given, Jaakko Pöyry (1)) to 661

Conventional Tissue
Fiber recycled on-site
Thermal energy generated on-site
Power purchased
Utilities includes waste water
fst = finished short ton (5% moisture)

APPENDIX I

TABLE I-A
CASES TO BE EVALUATED
(Values given, Jaakko Pöyry (1))

Mill type	Steam (MMBTU/ton)	Power kwh/ton	Gas MM BTU/ton
1-Conventional tissue in which fiber is recycled onsite, the thermal energy is generated onsite and the power is purchased.	9.2	626	1.8
1.1 The same data for a modern tissue machine	7.4	581	1.8
2-Recycled liner (test liner) in which fiber is recycled onsite, thermal energy is generated on-site and power purchased	5.1	450	
2.1 The same data for a modern test liner machine	4.0	310	
3-Fine paper where the fiber is purchased as pulp. Ditto energy	5.9	530	
3.1 The same data for a fine paper machine	3.9	410	
4-Coated 1,2,and 3 in which the chemical fiber is purchased. Ditto energy	6.7	720	
4.1 The same data for a coated paper machine	4.5	590	
5-Coated 4 and 5 in which the chemical fiber is purchased and the groundwood is produced on-site (TMP or similar process). Ditto energy.	6.7	1260	
5.1 The same data for a coated paper machine.	4.7	600	

TABLE I-B
FORMAT FOR RESULTS
GRADE: TEST (RECYCLE) LINER

Major Unit Operation	Steam (MM BTU/ton)	Power (kWh/ton)	Gas (MMBTU/ton)
Recycle Plant			
Paper Machine *	4.0	310	
Water, Effl. Treatment			
Utilities			
TOTAL	5.1	450	

* Includes stock prep, wet end, press section, dryers, dry end

Appendix II

Description of IPST Economic Mill Model and Plantation Model

IPST Economic Mill Model

Jaakko Pöyry Consulting (JPC) was sub-contracted to develop an assessment methodology for reviewing the impact of new technology on total mill operating and capital costs. Key components are mill design criteria, capital investment requirements, production costs, and profitability. A financial model-based methodology was developed which is based on a spreadsheet approach. Three Greenfield base cases were modeled: linerboard, UCFS, and newsprint facilities from the woodyard through shipping. Model validation, with input from IPST Member Companies, indicated the model results are reasonable.

Sensitivity analyses were run to assess key mill cost elements related to both capital and operating costs. These studies indicate that key items contributing to mill operating costs include costs of fiber (wood), labor, and energy, in addition to the cost of capital.

Model Details – Example – Integrated Uncoated Freesheet Model

Facility Description- The Base Case integrated uncoated freesheet model represents a hypothetical, 1995-vintage greenfield facility. The machine that was initially modeled is the machine that would have been built if an order had been placed in 1995. Capital and manufacturing costs are estimated to produce finished rolls, beginning in the woodyard.

The throughput of the bleached kraft mill for the base case run is 345,000 ADMT per year of unbleached pulp. The pulp mill provides 83% of the furnish (80%/20% hardwood/softwood), and the remainder is filler. Product is 75.2 g/m2 (46 lb/3M sq. ft.) uncoated freesheet produced at 1000 meters/min (3300 fpm)

Energy - The facility is modeled to be close to energy self-sufficient. A minimal amount of purchased power is shown since this is the case at the majority mills in North America. Steam demand is reported in lbs of steam, assuming a constant value of 1100 BTU per lb of steam in all instances. Steam produced at the kraft mill recovery boiler is directly tied to kraft pulp production and is only available for use if the pulp is consumed in the finished paper.

APPENDIX III

BIOGRAPHICAL SKETCH (CO-) PRINCIPAL INVESTIGATOR

NAME	DAVID E. WHITE
CURRENT AFFILIATION	IPST @ GEORGIA TECH – ATLANTA, GA
CURRENT POSITION	ASSOCIATE DIRECTOR, RESEARCH
GENERAL BACKGROUND SYNOPSIS	Responsible for providing research liaison support for the Director, carrying out the mission and objectives of the Institute, to assure that research activities/deliverables, intellectual property, and contract work are focused on customers' needs and take full advantage of Georgia Tech's expertise. Principal Investigator for research project in carbon sequestration; Co-Principal Investigator for research projects in fluid dynamics (Member Company funded) and forest biotechnology economics (CPBIS Sloan Center funded). Recently, Member of 1 IPST Ph.D. research committee (G. Delozier, Froth Air Flotation) and 2 M.S. research committees dealing with forest/pulp/paper economics. Chaired Administrative Processes Subcommittee during the successful 2002 Institute reaccredidation process. Key 23-year experience with Union Camp Corporation as research associate and research manager included engineering research in papermaking, separations, reactor design, start-ups, and mill modelling for environmental compliance.
PRIMARY SPECIALTIES	Creation of economic framework for market-based approaches for environmental solutions and energy conservation; biotechnology economic analysis; carbon sequestration Research portfolio management; economic analysis of research projects; identification of research deliverables; technology transfer, management related to research consortia Fluid mechanics of mixing
FIELDS OF INTEREST	Industrial research background: multi-phase pilot plant evaluation; computer modeling; papermaking; pulp bleaching; chemical and pulp/paper separations. Product line background: fine paper, coated board, linerboard, bag, saturating.
EDUCATION HISTORY	BS, University of Pennsylvania, Chemical Engineering – 1966. MS & Ph.D., University of Pennsylvania, Chemical Engineering – 1968/72.

PROFESSIONAL EXPERIENCE

1999 – 2003

INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY – World-renowned private graduate research university and research institute dedicated to the pulp and paper industry

Principal Research Engineer, Atlanta, GA - Responsible for providing research liaison support for the Director, carrying out the mission and objectives of the Institute, to assure that research activities/deliverables, intellectual property, and contract work are focused on customers' needs. Co-Principal Investigator for research projects in fluid dynamics (Member Company funded) and forest biotechnology economics (CPBIS Sloan Center funded). Member of 1 IPST Ph.D. research committee (G. Delozier, Froth Air Flotation) and 2 M.S. research committees dealing with forest/pulp/paper economics.

Director of Technology Transfer, Atlanta, GA - Responsible for carrying out the technology transfer mission of the Institute, in cooperation with the Assistant Vice President of Research (AVP-R); provided intellectual, administrative and technical leadership in planning, coordinating and managing the technology transfer activities and programs of the Institute. Responsible for assuring that IPST research activities are focused on customer's needs and that the research deliverables can be utilized by those customers.

Project Leader – Project ROCIT, Atlanta, GA – (Redefining Our Core Industry Technologies for the manufacture of paper and board products); identifying a set of new technologies that have the potential to make a significant change in the cost competitiveness of the U.S. pulp and paper industry. Research portfolio management; economic analysis of current and potential research projects; technology deliverables and transfer to industry.

1976 – 1999

INTERNATIONAL PAPER (FORMERLY UNION CAMP CORPORATION) Union Camp was a fully integrated forest products manufacturer of wood products, packaging, saturating, fine paper, and chemicals; merged with International Paper in 1999.

1998 - 1999

Senior Research Associate, Savannah, GA – Technology transfer group: evaluation of world-wide technologies suitable for implementation in Union Camp mills; mill troubleshooting; project scoping; liaison with outside research institutions.

1992 –1998

Research Associate, Princeton, NJ – Conducted independent laboratory/pilot research in conjunction with mills on high priority projects essential to strategic direction.

1982 – 1992

Group Leader, Papermaking Processes, Princeton, NJ – Oversaw process development and mill modernization research with emphases on paper machine capital effectiveness and mill environmental compliance. Managed team of five Ph.D. scientists and five

technicians.

1980 – 1982 — *Group Leader, Chemical Processes, Princeton, NJ* – Managed chemical process kinetics and separations research relating to feedstocks derived from wood.

1979 - 1980 — *Senior Research Scientist, Princeton, NJ* – Complex reactor design.

1976 – 1979 — *Research Scientist, Princeton, NJ* – Mill analysis; modelling for water use reduction.

1972 – 1976 — **E.I. DUPONT DE NEMOURS & CO.** – International chemical company. *Research Engineer, Waynesboro, VA* – Process development and scale-up. Mathematical modelling for process optimisation.

1971 – 1972 — **PRINCETON UNIVERSITY**– Princeton, NJ
Research Associate, Department of Chemistry – Experimental research in catalysis.

MAJOR PUBLICATIONS/ PRESENTATIONS RELEVANT TO THIS PROJECT

Peter, G.F., **White, D.E.**, de la Torre, R., Singh, R, and D. Newman, "Valuing Wood and Fiber Quality Traits for Pulp and Paper Production: The Role of Biotechnology in Reducing Costs", Submitted to International Journal of Biotechnology, Jan., 2005.

White, D. E., Peter, G. F., and M. Evans, "Effect of Recycled Paper Use on Print Quality", Submitted to GATF World Technology Forecast, December, 2004.

Peter, G. F., Fernandez, J., **White, D. E.**, Courchene, C., and G. A. Baum, "Impact of Forest Biotechnology on the Economics of Corrugated Box Production", Presented, TAPPI Engineering/Pulping Conference, Nov. 1, 2004, Atlanta, GA.

Peter, G.F., **White,** D.E., Sicarelli, N., de la Torre, R., Newman, D., "Commercialization of Forest Biotechnology: Economic Targets for Enhanced Global Competitiveness of the U. S. Pulp and Paper Industry", TAPPI Paper Summit, May 2004 CD-ROM.

Peter, G. F., Sorce, P., **White, D. E.**, and M. A. Evans, "Role of the Customer in Productivity Improvements in the Printing and paper Industries", Sloan Centers Conference, Atlanta, GA, April, 2004.

White, D. E., Peter, G. F., and M. Evans, "A Cross-Industry Systems Assessment of Future Printing and Papermaking Industry Trends", GATF World Technology Forecast, February, 2004.

MAJOR PUBLICATIONS/ PRESENTATIONS IN THE PAST FIVE YEARS

White, D. E., A. T. G. Giorges, and V. Bandhakavi, "Concentric Mixing of Softwood Pulp and Water", Presented, TAPPI Spring Technical Conference, May 5, 2004, Atlanta, GA.

DeLozier, G., Zhao, Y., Deng, Y., Zhu, J. Y., **White, D.**, and M. Prein, "Demonstration of Surfactant Spray Technology to Reduce Fiber Loss in Laboratory and Mill Operations", TAPPI Paper Summit, May 2004 CD-ROM.

Giorges, A. T., **White, D. E.**, and T. Heindel, "Concentric Mixing of Hardwood Pulp and Water", Tappi J 3(5), May 2004.

Work in fluid dynamics of mixing filed as provisional patent. Six publication/presentations from 1992-1996 on topics of pulp bleaching reactor design, mill modeling for environmental compliance and water savings. Chapters in books on pulp bleaching (1996) and wet pressing (1999). Seven U.S. patents on pulp bleaching. Program chair and session chair for TAPPI Eng. Conferences, 1999, 2000; 2003; 2005.